CONTROL BY SAMPLE LOCATION IN PIGEONS' MATCHING TO SAMPLE

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Three experiments assessed the impact of sample location in pigeons' matching to sample. Experiments 1 and 2 demonstrated that after line or hue identity matching was acquired to high levels of accuracy with center-key samples, varying sample location across the three keys disrupted performances. The drop in accuracy occurred following both zero-delay and simultaneous training and was mostly confined to trials in which the sample appeared on a side key. Experiment 3 attempted to diminish control by location by training birds to match samples that could appear in any location prior to center-key sample training and moving-sample testing with another set of stimuli. In testing, all birds performed accurately on center-sample trials and on side-key sample trials in which the matching choice appeared on the center key. Accuracy was below chance, however, on side-key sample trials in which the matching choice appeared on the other side key. One implication of the persistent control by sample location in the three-key paradigm is that it precludes the possibility of symmetry because symmetry tests require a change in the locations at which samples and comparisons appear.

Key words: sample location, matching to sample, moving-sample tests, symmetry, pecking, pigeons

Although the three defining properties of stimulus equivalence (reflexivity, transitivity, and symmetry) have routinely been demonstrated in humans (Sidman, 1994), clear and convincing evidence for these emergent relations in nonhumans has not been readily forthcoming. For example, despite reports of transitivity (D'Amato, Salmon, Loukas, & Tomie, 1985) and reflexivity (Oden, Thompson, & Premack, 1988) in some animals, symmetry (spontaneously matching Stimulus B to Stimulus A after reinforced training to match Stimulus A to Stimulus B) has been more elusive. Researchers have generally been unsuccessful in their attempts to demonstrate symmetry in pigeons and in nonhuman primates (D'Amato et al., 1985; Hogan & Zentall, 1977; Lipkens, Kop, & Matthijs, 1988; Sidman et al., 1982; but see Zentall, Sherburne, & Steirn, 1992).

Hogan and Zentall (1977, Experiment 1), for example, initially trained pigeons on symbolic matching to sample (MTS) with hue samples and comparisons. During subsequent symmetry tests, the sample–correct comparison relations in training were reversed for one (positive transfer) group. Thus, if red had originally been the correct comparison choice following a green sample, then green was the correct choice following the red sample in testing. For a second (negative transfer) group, the incorrect choice for each sample stimulus in training served as the conditional cue for selecting that stimulus in testing. Hogan and Zentall reported that subjects in both the positive and negative transfer groups matched at about chance levels (50%) during initial testing and that their performances did not diverge from one another with repeated testing. In short, neither first-session accuracy nor the relative rates of acquisition of class-consistent versus class-inconsistent MTS provided any evidence for symmetry.

One potential reason for negative findings like those reported by Hogan and Zentall (1977) is that the samples and comparisons change locations during the symmetry test. In the typical three-key MTS training procedure, the stimuli that serve as samples always appear on the center key, and those that serve as comparisons always appear on the side keys. In testing, however, the former samples now appear on the side keys as comparisons, and the former comparisons now appear on the center key as samples—that is, in loca-

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Table 1

Twelve possible configurations resulting from the moving sample procedure for simultaneous and zero-delay matching to sample. The simultaneous configurations appeared in Iversen et al. (1986).

Group	Center sample baseline		Center correct ("old")				Side correct ("new")			
			Left sample		Right sample		Left sample		Right sample	
SM	V<u>V</u>H H<u>V</u>V H<u>V</u>V V<u>H</u>H		<u>V</u>VH <u>H</u>HV		HV<u>V</u> VH<u>H</u>		<u>V</u>HV <u>H</u>VH		VH<u>V</u> HV<u>H</u>	
ZD	Sample	Comparisons	Sample	Comparisons	Sample	Comparisons	Sample	Comparisons	Sample	Comparisons
	_V_	V_H	V_ _	_VH	_ _V	HV_	V_ _	_HV	_ _V	VH_
	_V_	H_V	H_ _	_HV	_ _H	VH_	H_ _	_VH	_ _H	HV_
	_H_	V_H								
	_H_	H_V								

Note. SM = simultaneous, ZD = zero delay, V = vertical lines, H = horizontal lines. The underlined letters represent the sample stimulus. Darkened keys in the zero-delay condition are represented by _.

tions where they have never before appeared. This shift in location is problematic if, for example, red on the center key is a different stimulus for the animal than red on the side key (Iversen, Sidman, & Carrigan, 1986; Lipkens et al., 1988; Sidman, 1994). In other words, the animal may not simply learn in training to choose between the comparisons when the sample is red (as the experimenter assumes) but instead to choose on the basis of "center red." Consequently, shifting the center-key (sample) stimuli to the side keys and the side-key (comparison) stimuli to the center key will yield functionally different stimuli, thus precluding symmetry.

Iversen et al. (1986) investigated the possible role of spatial location as a controlling characteristic of stimuli in rhesus monkeys that had been trained on two simultaneous identity matching tasks, one involving red and green hues and another involving vertical and horizontal lines. During training, the samples always appeared on the center key and the comparisons always appeared on two adjacent side keys. In testing, the sample could appear on any of the three keys (with the comparisons appearing on the remaining two keys).

Iversen et al. (1986) reasoned that if matching performances in training did not depend upon sample location, then moving the sample to one or the other side key in testing should have little effect on matching accuracy. By contrast, if the functional sam-

ples in training included the location where they had appeared, then a switch in location should disrupt performance. Iversen et al. found that line-matching accuracy was disrupted in the moving-sample test, whereas hue-matching accuracy was not. In addition, they reported that the disruptive effect of moving the line samples was confined to trials on which the sample appeared on a side key, and that the drop in accuracy on the latter trials depended upon the stimulus configuration displayed at the time of choice.

As shown in the top half of Table 1, the configuration on some left- and right-sample test trials in the Iversen et al. (1986) procedure was identical to a configuration seen in training. On these trials, called "old" by Iversen et al. and labeled "center correct" in the table, the correct comparison appeared on the center key. On other test trials, the three-key configuration was unlike anything seen in training. These trials (called "new" by Iversen et al.) are labeled "side correct" because the correct comparison appeared on the side key opposite to that on which the sample was displayed.

Although accuracy on both center- and side-correct trials was lower than on baseline (training) trials, both monkeys in the Iversen et al. (1986) study correctly matched more often on side-correct trials (i.e., 80% correct or better) than on center-correct trials (below 50% correct). This difference may have arisen because, after seeing a line sample in a

new (side-key) location, the monkeys did what they had learned to do in training: press a side-key stimulus. Because pressing the side key on which the sample itself appeared had no effect following the initial response, switching to the other side key would yield high levels of accuracy on side-correct trials and very low levels of accuracy on center-correct trials, as observed in the first test session.

The configurational differences observed by Iversen et al. (1986) are noteworthy because they suggest that simultaneous matching may pose complications in any effort to find symmetry. Specifically, because all three keys are lit at the time of choice, animals may learn in training to respond to one spatial location or another given a particular three-key stimulus display (e.g., in symbolic MTS, respond left to a vertical-red-horizontal display and respond right to a horizontal-red-vertical display). Although evidence for configural learning in MTS by pigeons is admittedly very weak (Carter & Werner, 1978; Kamil & Sacks, 1972; Wright & Sands, 1981), it is probably unwise to dismiss it as a potential source of control over choice. If such control, however weak, were to develop during simultaneous MTS training (Wright, 1992), then it would further reduce any chance of obtaining symmetry.

In view of this consideration and of the results of Iversen et al. (1986), Experiments 1 and 2 of the present paper were designed to compare the sensitivity of simultaneous versus zero-delay MTS performances by pigeons to changes in sample location. In this way, we evaluated the possibility that removing the sample at the time of comparison presentation (as in the zero-delay procedure) might alleviate at least some of the disruption we expected to see in simultaneous MTS when the samples were moved from their fixed center-key location to side-key locations in testing. These experiments also assessed the replicability of Iversen et al.'s findings with pigeons, which are frequently used in conditional discrimination studies (e.g., Hogan & Zentall, 1977; Lipkens et al., 1988; Urcuioli, Zentall, & DeMarse, 1995; Wasserman, De-Volder, & Coppage, 1992; Zentall & Urcuioli, 1993).

EXPERIMENT 1

One purpose of Experiment 1 was to see whether the Iversen et al. (1986) moving-sample results were replicable with pigeons. Would accuracy of matching drop when the samples appeared in locations other than their familiar, center-key position? Would performances differ on center-correct ("new") versus side-correct ("old") test trials? A second purpose was to compare these performances when the sample was present at the time of choice (simultaneous matching) versus absent (zero-delay matching). The rationale here was twofold. First, the zero-delay procedure should remove any effect of three-key configurations on choice. Second, and more important, removing the sample prior to comparison presentation might make temporal position (rather than location) a more salient characteristic of the sample. In other words, birds trained on zero-delay MTS might learn that the sample is whatever stimulus appears first. If they do so, then they should maintain relatively higher levels of accuracy during moving-sample tests than birds trained on simultaneous MTS.

METHOD

Subjects

The subjects were 8 White Carneau pigeons obtained from the Palmetto Pigeon Plant. All pigeons had previous MTS experience, mostly in differential outcomes studies (e.g., Urcuioli & DeMarse, 1997) with stimuli or matching contingencies (or both) different from those used here. Birds were maintained at 80% of their free-feeding weights and earned their food during the experimental sessions. Birds were housed individually in stainless-steel wire-mesh cages in a room on a 14:10 hr light/dark cycle. Water and pigeon grit were freely available in the home cage. Prior to the start of the experiment, the pigeons were divided into two groups of 4.

Apparatus

The apparatus consisted of two standard conditioning chambers (BRS/LVE Model SEC-002), each containing a Model PIP-016 three-key panel. Each response key measured 2.5 cm in diameter and was located 5.7 cm from the adjacent keys, forming a horizontal row 7.5 cm from the top of the panel. Each key was equipped with an inline projector mounted directly behind it, and each projector could display three white vertical or hor-

izontal lines on a black background (BRS/LVE Pattern 696). The food hopper opening, measuring 5.8 cm by 5.8 cm, was located 9 cm below the center response key. Each chamber was illuminated by a GE 1829 houselight located on the top center of the panel. Mounted on the outside of each chamber was a blower fan that provided masking noise and ventilation. Data were collected and experimental events were controlled by a Zenith 286 computer.

Procedure

All birds were given 1 day of preliminary training to peck vertical and horizontal lines on the center key and 1 day of training to peck those same stimuli on both the center and side keys. At the start of every trial, a stimulus appeared on one of the keys and remained lit until a peck was made to it. A response turned off the stimulus and provided food for a fixed duration of 3 s. Each session consisted of 60 trials, with successive trials separated by a 10-s intertrial interval (ITI).

All birds were then trained to match three vertical and three horizontal line samples to identical vertical- and horizontal-line comparisons, respectively. Matching trials began with presentation of either the vertical or the horizontal lines on the center key. Two pecks to the line sample then produced vertical and horizontal comparisons on the side keys. For birds assigned to Group SM (simultaneous), the center-key sample remained on throughout comparison selection. For birds assigned to Group ZD (zero delay), the center-key sample was turned off when the vertical and horizontal comparisons appeared. Additional pecks to the center key (whether lit or dark) after the comparisons appeared had no programmed consequences. A single peck to either comparison turned off all stimuli and delivered reinforcement if the matching comparison was chosen. If the nonmatching comparison was pecked, all stimuli and the houselight were turned off for a period equivalent to the reinforcement duration. A noncorrection procedure was used: An incorrect choice did not cause the trial to be repeated. Following reinforcement or timeout, a 10-s ITI began, the first 9 s of which were spent in darkness. The houselight was turned on for the last 1 s of the ITI and remained on until the end of the following trial. Reinforce-

ment varied between 2 and 6 s across sessions in such a way that birds were maintained at their 80% weights. Training sessions consisted of 96 trials and were continued for a minimum of 10 days and until each bird reached a criterion of 90% or better accuracy on 5 of 6 successive days. Sessions were conducted 6 days per week.

Reinforced testing began once the acquisition criterion had been reached. In testing, all birds were still required to match vertical and horizontal samples to vertical and horizontal comparisons, respectively, but now the sample could appear on any of the three keys. Consequently, the comparisons were also no longer restricted only to the side keys. As in training, birds in Group SM still experienced simultaneous matching and birds in Group ZD still experienced zero-delay matching. Moving-sample test sessions were conducted until 90% or better accuracy was reached on 5 of 6 successive days, or for a maximum of 30 sessions.

Moving the sample to new locations during testing produced a set of new sample-comparison configurations or arrangements relative to those appearing in training (see Table 1). For Group SM, the configurations corresponded to those used by Iversen et al. (1986). Baseline trials consisted of a center-key sample and two side-key comparisons, as in training. By contrast, when the sample appeared on a side key, the configuration and the order in which the bird was required to peck the keys were different. In some cases, the side-key sample produced a configuration identical to one seen in training, but with the correct comparison now located on the center key. Such trials are called "center correct" (Iversen et al.'s "old" trials). On the remaining trials, the configuration differed from any the bird had previously seen: Both the sample and correct comparison were located on a side key. These trials are called "side correct" (Iversen et al.'s "new" trials). Each 96-trial session included an equal number of baseline, center-correct, and side-correct trials.

Data Analyses

Statistical evaluation of overall effects within and between groups initially involved analyses of variance (ANOVAs). Where appropriate, these were followed by post hoc contrasts on the group means using the methods, ta-
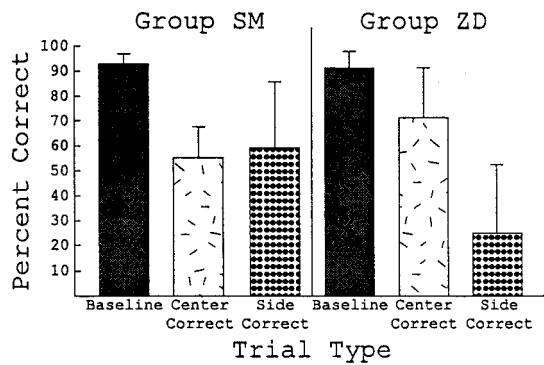
Fig. 1. Performance by trial type on the 1st day of testing in Experiment 1 for both groups.

bled *F* values, and inferential techniques described by Rodger (1975a, 1975b). Type I error rate was set at .05.

RESULTS

In training, Group SM reached criterion levels of matching accuracy (90% correct) sooner than Group ZD, $F(1, 6) = 7.28$. Group

SM needed 13 sessions on average to reach criterion (range, 6 to 23 sessions) versus 34 sessions for Group ZD (range, 24 to 53 sessions). However, by the end of training, performances in the two groups were comparable: Matching accuracy over the last 5 days prior to testing averaged 93.9% correct in Group SM and 93.8% correct for Group ZD, $F(5, 30) = 0.70$.

Figures 1, 2, and 3 show mean accuracy on all three trial types presented during testing (cf. Table 1). Figure 1 depicts performances averaged across the 4 subjects in each group on the first session of testing. Figures 2 and 3 show individual-subject data for Groups SM and ZD, respectively, for all test sessions and for the last five training (T) sessions that preceded testing.

In the first test session (Figure 1), matching accuracy on baseline trials for both groups was 90% correct or better. On moving-sample trials, performances were clearly disrupted relative to baseline with the pattern of disruption differing somewhat between
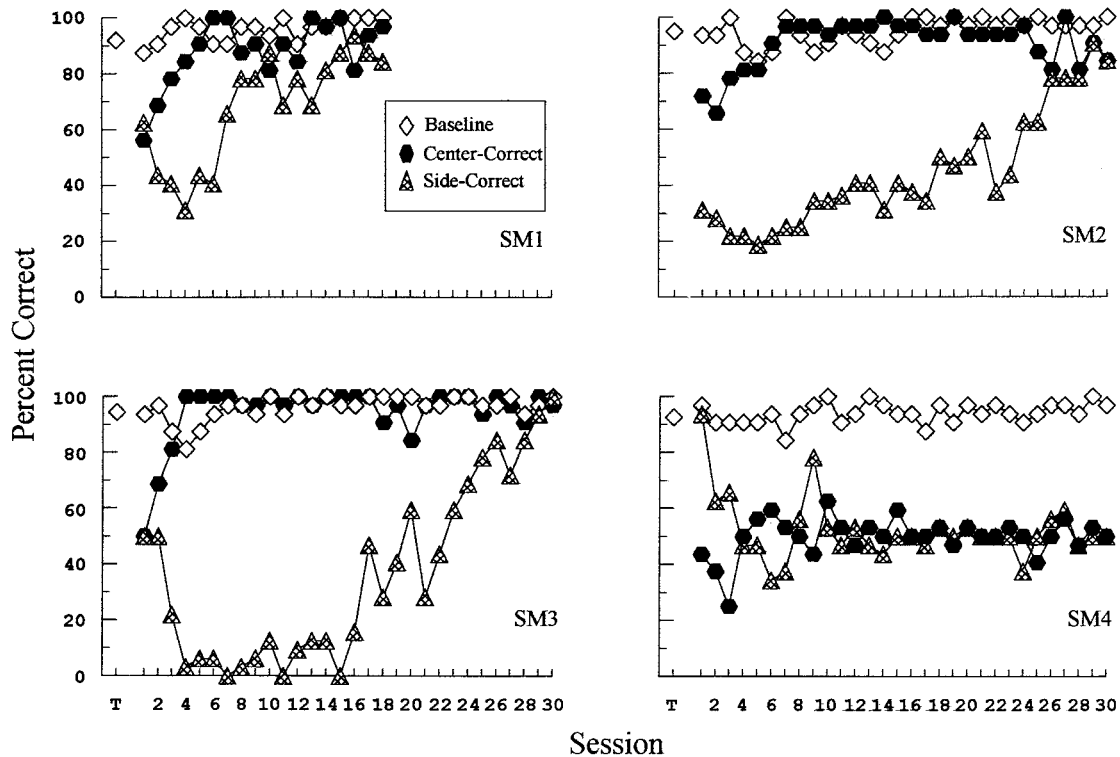

Fig. 2. Percentage correct for each subject in Group ZD for 30 test sessions in Experiment 1. Average performance over the last five training sessions preceding testing is indicated by T.
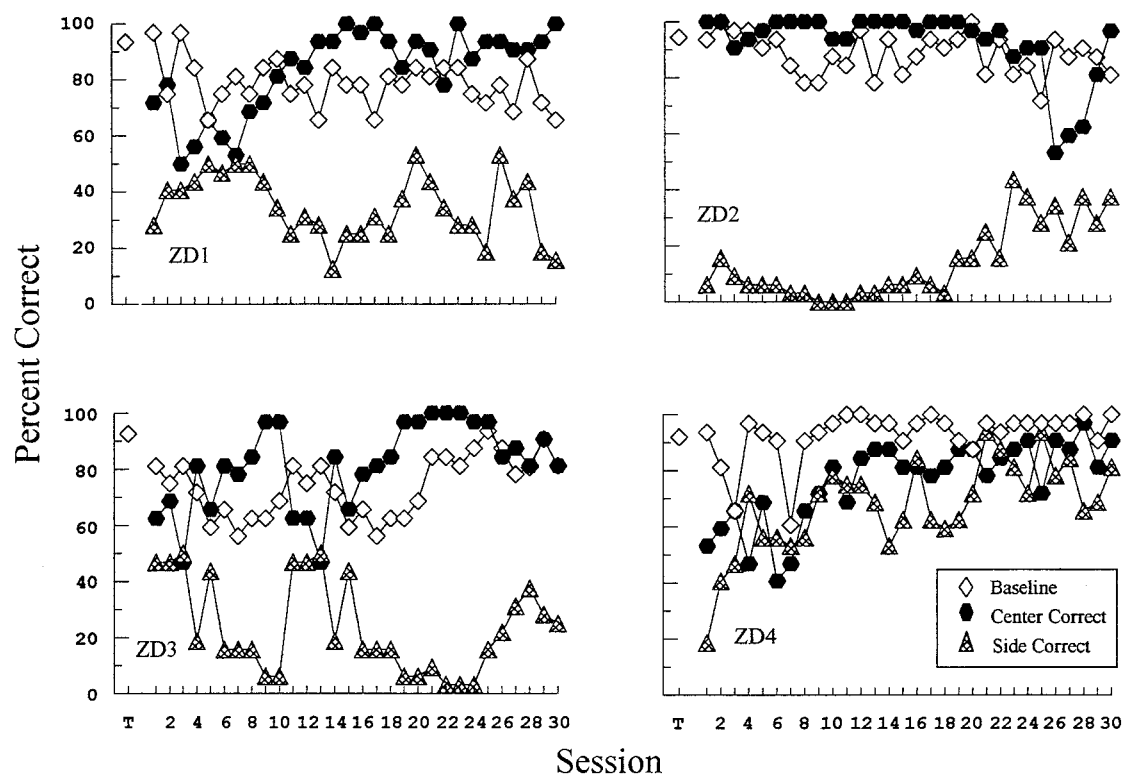
Fig. 3.   Percentage correct for each subject in Group SM for 30 test sessions in Experiment 1. Average performance over the last five training sessions preceding testing is indicated by T.

groups. Specifically, Group SM performed at close to chance levels of accuracy (55% to 60% correct) on both center- and side-correct trials, whereas matching accuracy for Group ZD was appreciably higher, on average, on center-correct (70% correct) than on side-correct trials (25%). Post hoc contrasts on the data from Group SM confirmed that performance was considerably more accurate on baseline trials than on either center-correct or side-correct test trials, $F(2, 6) = 4.57$, which did not differ from one another, $F(2, 6) = 0.04$. For Group ZD, matching was less accurate on side-correct trials than on baseline trials, $F(2, 6) = 13.16$, with accuracy on center-correct trials midway between these two extremes, $F(2, 6) = 0.74$ (Rodger, 1975b, Equation 23).

The individual-subject data in Figures 2 and 3 show a good deal of consistency both within and between groups. For example, on Day 1, most birds maintained very high levels of accuracy on baseline trials. On center-correct and side-correct test trials, accuracies

were, with only two exceptions, considerably lower. The two exceptions were Bird SM4 on side-correct test trials (93.8%) and Bird ZD2 on center-correct trials (100%). However, on subsequent test sessions, Bird SM4's performance on side-correct trials fell into the range shown by the other birds in its group.

With repeated testing, a number of trends were evident in the data. First, high levels of accuracy on baseline trials were consistently maintained in Group SM, whereas baseline performances in Group ZD (with the possible exception of Bird ZD2) were very erratic. Second, 3 of the 4 SM birds and 3 of the 4 ZD birds regularly chose the correct comparison on side-correct trials much less often than on center-correct trials, with accuracies often much lower than chance on side-correct trials. Third, performances on center-correct trials, if initially disrupted, recovered to high levels of accuracy by the end of testing (the only exception being Bird SM4). By contrast, only 3 birds (all in Group SM) were matching

at high levels of accuracy on side-correct trials by the end of testing.

DISCUSSION

The results of Experiment 1 demonstrate that the spatial location of the sample stimulus is a controlling feature in pigeons' MTS. Moreover, zero-delay training does not diminish the disruption caused by moving samples to new locations following center-key training in simultaneous MTS. In general, birds chose the correct comparison less often in testing when the sample appeared on the left or the right side key than when it appeared on the center key.

The disruptive effect of moving the sample to new locations replicates the effect reported by Iversen et al. (1986) for simultaneous line matching by monkeys. In that study, high levels of accuracy in testing were maintained when the sample appeared on the center key, but not when the sample appeared on a side key. The present study extends this finding to pigeons and to subjects trained and tested on zero-delay matching.

Interestingly, performances by the Group SM birds across successive test sessions suggest that their choices may have been partly influenced by configuration. Specifically, by the fourth or fifth test session, 3 of the 4 SM birds chose the correct comparison as often on center-correct test trials as on baseline trials. By contrast, side-correct performances were considerably less accurate. Given Group SM's training history, the three-key configurations on center-correct trials would be more familiar than those on side-correct trials. Thus, discounting the initial effect of shifting from training to testing, quicker recovery in performance on center-correct trials would be expected if the familiarity of the configuration influenced performance.

However, this account does not readily explain why performances by the Group ZD birds were also considerably less accurate on side-correct than on center-correct trials throughout most of testing. After all, because the samples were absent at the time of comparison choice for Group ZD, there were no three-key displays either in training or in testing. The pattern of results in this group (and perhaps in Group SM) might have arisen if birds preferentially pecked the lit key closest to the location where the side-key sample appeared regardless of what comparison was presented on it (i.e., the center key). This would yield relatively high accuracy on center-correct trials and, conversely, relatively poor accuracy on side-correct trials, as observed.

Pecking the closest lit key following a side-key sample might reasonably be expected given the response pattern preceding reinforcement during training: pecking an adjacent side key after pecking the center-key sample. Furthermore, 66% of the moving-sample test trials began with a side-key sample and, on one half of these, pecking the adjacent center key produced reinforcement. Thus, continued (albeit partial) reinforcement for the behavioral sequence of pecking two adjacent keys may explain the center-correct versus side-correct trial-type difference seen immediately in Group ZD and its development over successive test sessions in the Group SM birds.

The most important finding, however, was that matching performances by all birds were disrupted by moving the sample from the center to the side keys. It is clear, then, that location is a controlling characteristic of the samples in pigeons' MTS: A line stimulus on the center key is not the same as the identical line stimulus on the left or right key.

EXPERIMENT 2

Given the results of Experiment 1, the next question was whether or not the moving-sample effect is specific to line stimuli. For instance, would matching performances also be disrupted using hue stimuli? In Iversen et al.'s (1986) study, monkeys' hue identity matching appeared to be relatively immune to changes in spatial location. Would the same be true of pigeons? In Experiment 2, then, pigeons were trained to match red and green center-key samples to red and green side-key comparisons. Afterwards, sample location was varied in the same manner as Experiment 1.

METHOD

Subjects and Apparatus

Four birds from Experiment 1 (SM1, SM3, ZD1, and ZD4) and 8 additional birds served as subjects. The latter birds had previous experience on MTS with center-key samples in

an unrelated differential outcomes task involving different hue and form stimuli. Prior to training, the 12 birds were divided into two groups of 6. The groups were balanced with respect to the birds' previous training histories with the exception that the Group ZD birds from Experiment 1 continued on zero-delay MTS and the Group SM birds continued on simultaneous MTS. Housing conditions were the same as in Experiment 1.

The apparatus was the same as in Experiment 1, except that each inline projector was equipped to display red and green homogeneous fields.

Procedure

Preliminary training to establish pecking to red and green on the center and side keys was similar to that used to establish pecking to the line stimuli in Experiment 1. Following preliminary training, all birds immediately began training on hue identity MTS with center-key samples. A zero-delay procedure was used for Group ZD, and a simultaneous matching procedure was used for Group SM. Other than the change in stimuli to red and green hues, all other procedural details were identical to those used in Experiment 1.

After each bird reached an acquisition criterion of 90% or better accuracy on five of six successive MTS training sessions, it was then tested for 10 sessions during which the hue samples (and comparisons) could appear on any of the three keys. Details of these moving-sample test sessions were identical to those used in Experiment 1.

RESULTS AND DISCUSSION

ANOVA indicated that acquisition was significantly more rapid in Group SM than Group ZD, $F(1, 10) = 15.93$: The average number of sessions to reach criterion was eight for Group SM (range, 6 to 9 sessions) versus 13 for Group ZD (range, 8 to 16 sessions). However, by the end of training, performances were comparable in the two groups. Matching accuracy over the last five sessions prior to moving-sample testing was 95.9% correct for Group SM and 95.3% correct for Group ZD, $F(1, 10) = 0.73$.

Figures 4, 5, and 6 show accuracy by trial type during testing by group (Figure 4) and for individual subjects (Figures 5 and 6). The group data have been collapsed across sub-
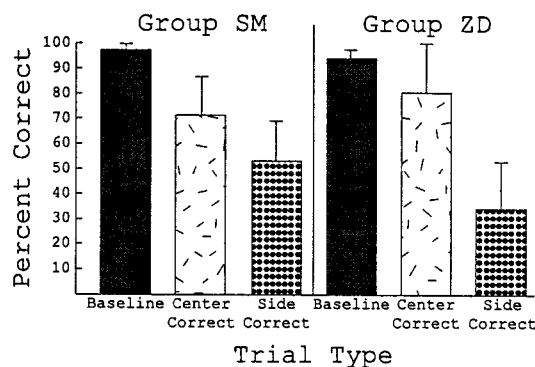

Fig. 4. Performance by trial type on the 1st day of testing in Experiment 2 for both groups.

jects with and without prior moving-sample experience because ANOVA indicated that there were no differences in first-session performances as a function of this variable, $F(1, 8) = 0.32$.

Averaged data from the first test session (Figure 4) show that both groups maintained high accuracy (90% correct and above) on baseline trials. Moving the sample to the left or right side keys, however, clearly disrupted performance, and the pattern of disruption was similar to that seen in Experiment 1. On center-correct trials, Groups SM and ZD chose the matching hue comparison 77% and 81% of the time, respectively. On side-correct trials, matching accuracy was at chance levels in Group SM (53%) and below chance in Group ZD (35%). Post hoc contrasts on the data from Group SM confirmed that matching was more accurate on baseline trials than on center-correct and side-correct trials, $F(2, 10) = 17.50$, which did not differ from one another, $F(2, 10) = 3.20$. For Group ZD, baseline and center-correct trial accuracies were comparable, $F(2, 10) = 0.76$, but were considerably higher than on side-correct trials, $F(2, 10) = 8.70$.

Across the 10 test sessions (see Figures 5 and 6), a number of trends were apparent in the data. First, with the brief exception of ZD4, all birds maintained high levels of matching accuracy on the baseline trials. Second, whereas 3 of the 6 Group SM birds and 5 of the 6 Group ZD birds chose the correct hue comparison substantially more often on center-correct than on side-correct trials on the first test session, there was even greater consistency across subjects on this trial-type
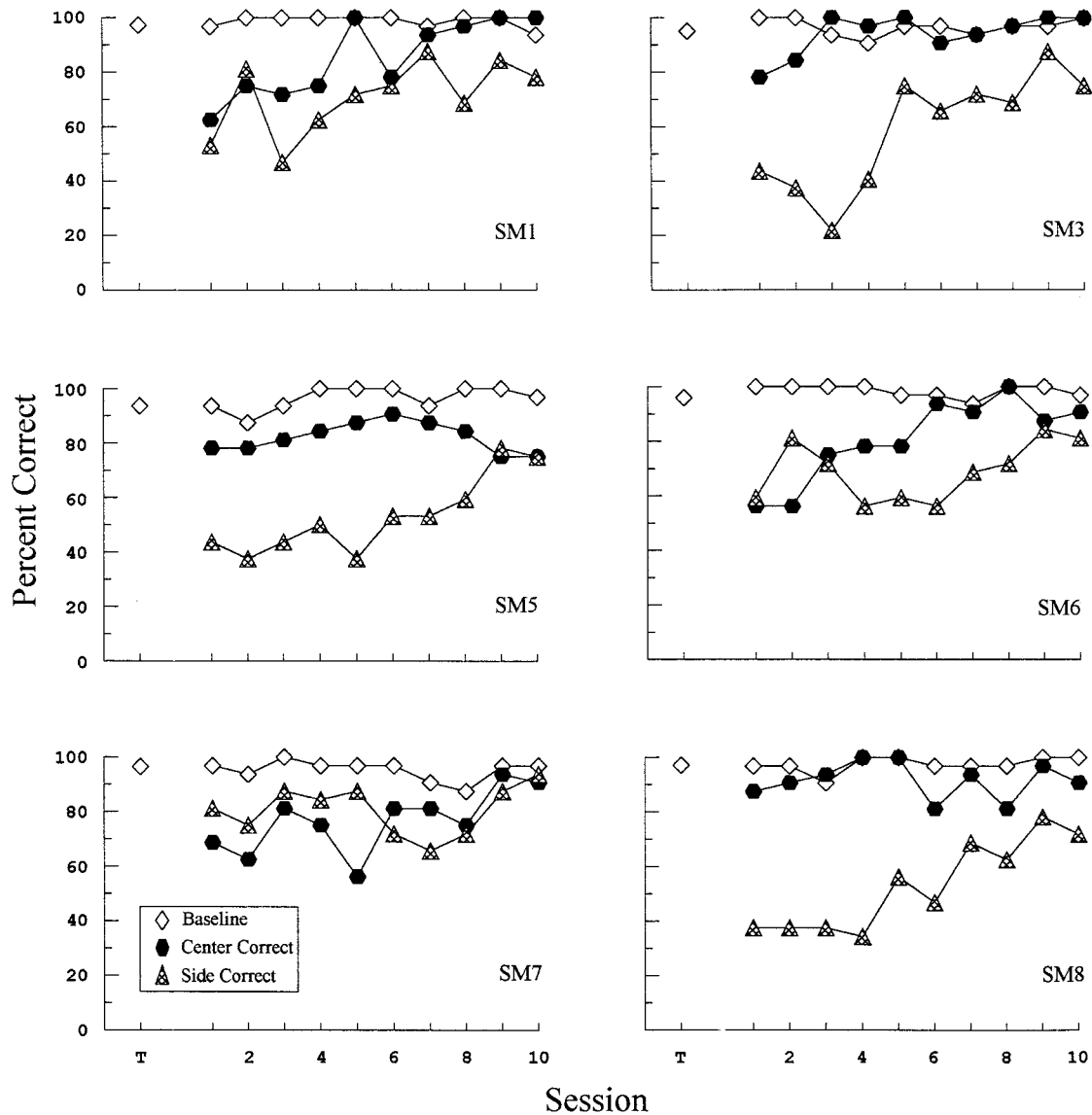
Fig. 5. Percentage correct for each subject in Group ZD for 30 test sessions in Experiment 2. Average performance over the last five training sessions preceding testing is indicated by T.

difference with repeated testing. Third, many birds were below chance in their choices on side-correct trials at some point during testing. Finally, accuracy on center-correct trials eventually approximated accuracy on baseline trials for all but 1 bird (SM5). By contrast, by the end of testing, only 4 birds (SM7, ZD4, ZD7, and ZD8) correctly matched on side-correct trials at levels comparable to those observed on their baseline trials.

The results of this experiment, then, demonstrate that spatial location is also a controlling feature in pigeons' hue matching. Although all birds performed accurately on baseline trials in testing, moving the sample from the center key to one of the side keys disrupted performances. This finding differs from that of Iversen et al. (1986), who showed that monkeys' hue matching was relatively unaffected by moving samples to new locations. Moreover, as in Experiment 1, zero-delay training did not
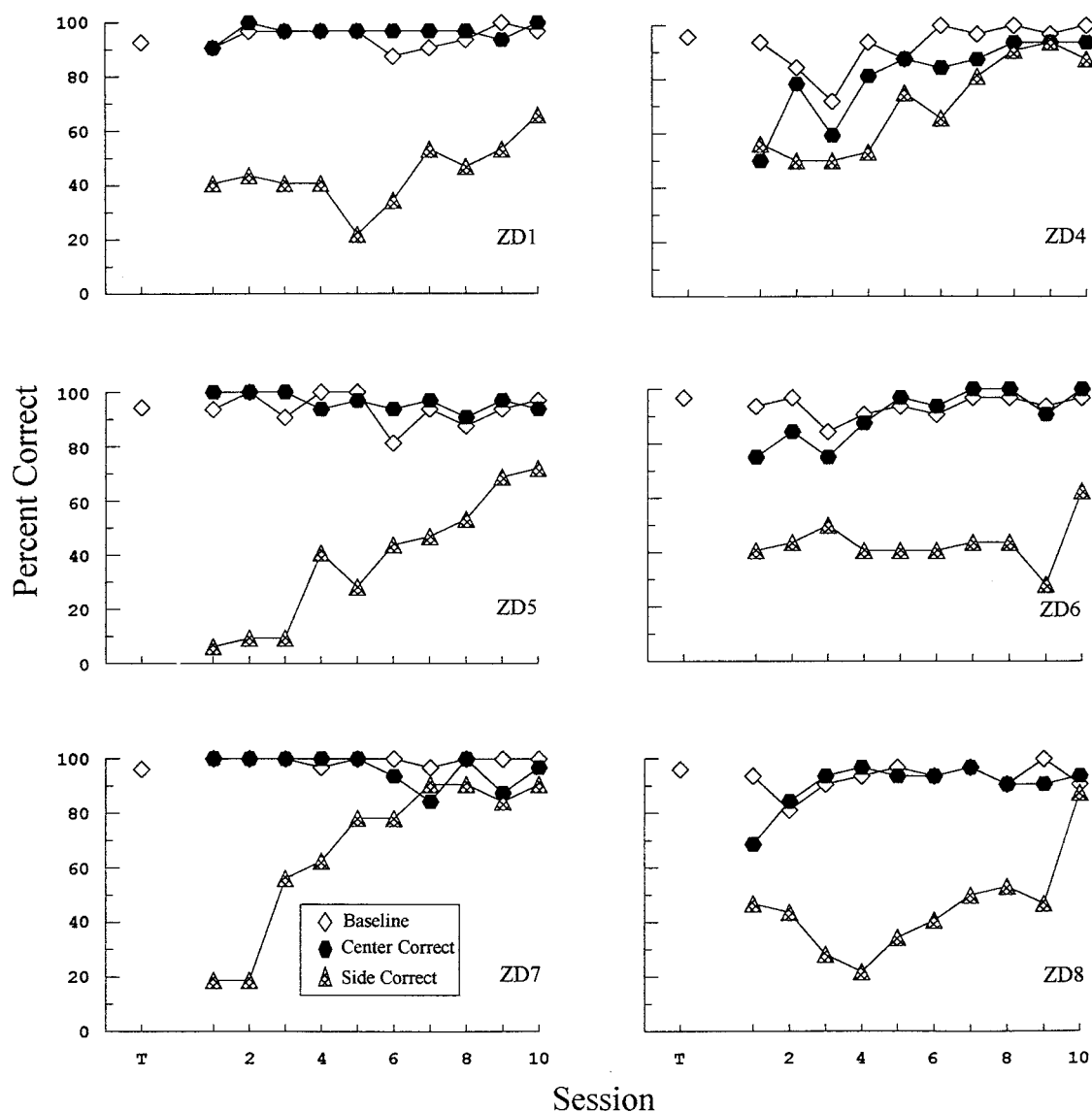
Fig. 6.   Percentage correct for each subject in Group SM for 30 test sessions in Experiment 2. Average performance over the last five training sessions preceding testing is indicated by T.

reduce the moving-sample effect relative to simultaneous MTS.

Finally, in this experiment, too, the majority of the birds preferentially pecked the center-key comparison on side-key-sample test trials. This is indicated both by the pattern of greater accuracy on center-correct than on side-correct trials and by the below-chance accuracies observed in many birds on the latter test trials.

EXPERIMENT 3

Given the pronounced effect of stimulus location on pigeons' MTS observed in Experiments 1 and 2, we wondered whether there might be a way to reduce or prevent spatial location from becoming a controlling characteristic of samples. We hypothesized that if the sample were varied among all three keys *during training*, this might diminish control by location relative to the sample's visual char-

Table 2
Procedure used in Experiment 3.

	Phase 1	Phase 2	Testing
Group CS	R → R+ G → G+ Center sample	V → V+ H → H+ Center sample	V → V+ H → H+ Moving sample
Group MS	R → R+ G → G+ Moving sample	V → V+ H → H+ Center sample	V → V+ H → H+ Moving sample

Note. Moving and center sample refer to the type of procedure used. R, G, V, and H represent red, green, vertical, and horizontal stimuli, respectively. Samples and correct (+) comparisons appear to the left and right, respectively, of the arrows.

acteristics. If so, then after additional MTS training with *different* stimuli and center-key samples, birds should be better able to match those stimuli to one another in a moving-sample test. In short, Experiment 3 addressed the following question: Will prior experience with varied sample locations in one MTS task permit birds to accurately match other samples regardless of where the latter appear? To answer this question, birds were initially trained on a moving-sample MTS task with hue stimuli after which they acquired a second MTS task with line stimuli and center-only samples. Finally, birds were tested on line matching with those samples now varying in their location.

METHOD

Subjects and Apparatus

Twelve experimentally naive White Carneau pigeons, obtained from the Palmetto Pigeon Plant and maintained at 80% of their free-feeding weights, served as subjects. Water and health grit were available at all times in the home cage, and general housing conditions were identical to those in Experiment 1. Prior to training, the birds were divided into two groups of 6.

The apparatus was the same as in Experiment 1. Horizontal and vertical line stimuli as well as red and green stimuli were used in this experiment.

Procedure

All birds were initially trained to eat from a lit food hopper; then they were taught by the method of successive approximations to peck an inverted white triangle on the center key. Next, they received 4 days of preliminary

training to peck the stimuli that would later appear as samples and comparisons in MTS. The first 2 days of preliminary training consisted of a center-key-only session with red and green followed by a second session in which these two hues appeared singly on all three keys. The same sequential procedure was then followed on the last two preliminary training sessions to establish pecking to vertical and horizontal lines. Each stimulus in these sessions appeared 30 times and, when presented on all three keys, appeared equally often at each location. All other details were the same as those for the corresponding sessions in Experiments 1 and 2.

In Phase 1, both groups were trained on zero-delay identity MTS with red and green hues (see Table 2). For Group MS (moving sample), the sample for a given trial could appear on the side keys as well as on the center key. By contrast, Group CS (center sample) always saw the hue samples on the center key. For both groups, matching choices were followed by food, and nonmatching choices were followed by a timeout. All other procedural details for these sessions were identical to those previously described.

Each bird remained in Phase 1 for a minimum of 10 days and until it reached a criterion of 90% correct or better accuracy for 5 of 6 successive days. In addition, Group MS had a further criterion of at least 87.5% accuracy for center, left, and right samples in order to insure consistent performance across different sample locations.

In Phase 2, all birds learned identity matching with vertical and horizontal samples and comparisons and with center-key samples only. Correct (i.e., matching) choices were

followed by food, whereas incorrect (i.e., nonmatching) choices were followed by the timeout. As in Phase 1, each bird remained in Phase 2 for a minimum of 10 days and until it met a criterion of 90% or better accuracy for 5 of 6 successive days. After completing Phase 2, birds were given at least one refresher session on both their Phase 1 and Phase 2 tasks. Refresher sessions were continued until criterion levels of accuracy were reestablished for each task.

Finally, both groups were tested on line matching with moving samples. In testing, each line sample appeared an equal number of times on each key. The same contingencies (with regard to correct and incorrect choices) that were established in Phase 2 were also in effect in testing. All birds were tested for a minimum of 10 sessions and until 90% accuracy was reached or until 30 test sessions were conducted.

RESULTS AND DISCUSSION

During Phase 1, Group CS reached criterion levels of accuracy in an average of 20 sessions (range, 12 to 40 sessions) compared to 25 sessions for Group MS (range, 10 to 44 sessions). ANOVA indicated that this difference was not significant, $F(1, 10) = 0.12$. Average performances for the last 5 days of Phase 1 were 93.8% and 93.7% correct for Groups CS and MS, respectively, $F(1, 10) = 0.03$.

Acquisition to criterion of the line-matching task in Phase 2 required an average of 36 sessions in Group CS (range, 14 to 100 sessions) versus 33 sessions in Group MS (range, 15 to 100 sessions). ANOVA indicated that this difference was not significant, $F(1, 10) = 0.00$. By the end of Phase 2, all but 2 birds were matching at 90% accuracy or better; average performances over the last 5 days of Phase 2 were 92.8% and 93.4% correct for Groups CS and MS, respectively, $F(1, 10) = 0.49$. Although 1 bird from each group did not meet the criterion after 100 sessions, their performances over the last five sessions were quite accurate (87.5%), so each was moved to the test phase.

Group data by trial type for the first moving-sample test session are shown in Figure 7. Individual-subject data by trial type for all 30 test sessions appear in Figures 8 and 9 for Groups CS and MS, respectively. On the first test session, high levels of matching accuracy
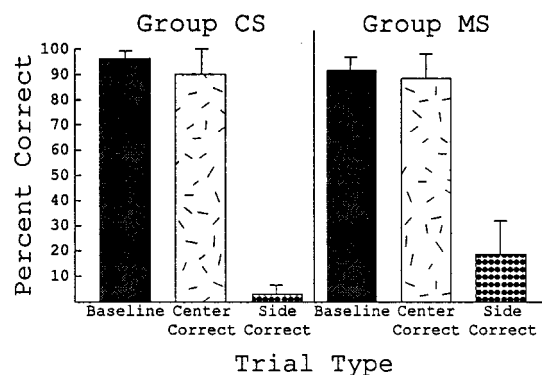

Fig. 7.   Performance by trial type on the 1st day of testing in Experiment 3 for both groups.

were observed in both groups on baseline trials and on center-correct test trials. By contrast, accuracy on side-correct test trials was well below chance in both groups. Post hoc contrasts on the group means showed the same pattern of statistical results. In neither group was accuracy on center-correct trials significantly different from that on baseline trials, $F(2, 10) = 1.13$ and 0.15 for Groups CS and MS, respectively. By contrast, accuracy in both groups was higher on center-correct than on side-correct test trials, $F(2, 10) = 218.33$ and 61.29 for Groups CS and MS, respectively.

The individual-subject results (see Figures 8 and 9) show that all birds matched at or above 87.5% correct on baseline trials on the first test session. On center-correct test trials, all birds in Group CS chose the correct comparison at least 75% of the time, with 4 of the 6 birds choosing correctly on at least 87.5% of these trials. In Group MS, 5 of the 6 birds matched at 87.5% accuracy or better on the center-correct trials. On side-correct test trials, no CS bird (except CS2) chose the correct comparison more than 10% of the time. Similarly, all MS birds matched well below chance on these trials, although the range of accuracy in this group was greater than in Group CS.

Over repeated test sessions, most birds maintained their relatively high baseline-trial accuracies, although there was quite a bit of session-to-session variability for many subjects. Performances on center-correct trials, which were highly accurate at the outset of the moving-sample test (except for Bird MS5), remained so throughout the 30 test sessions for
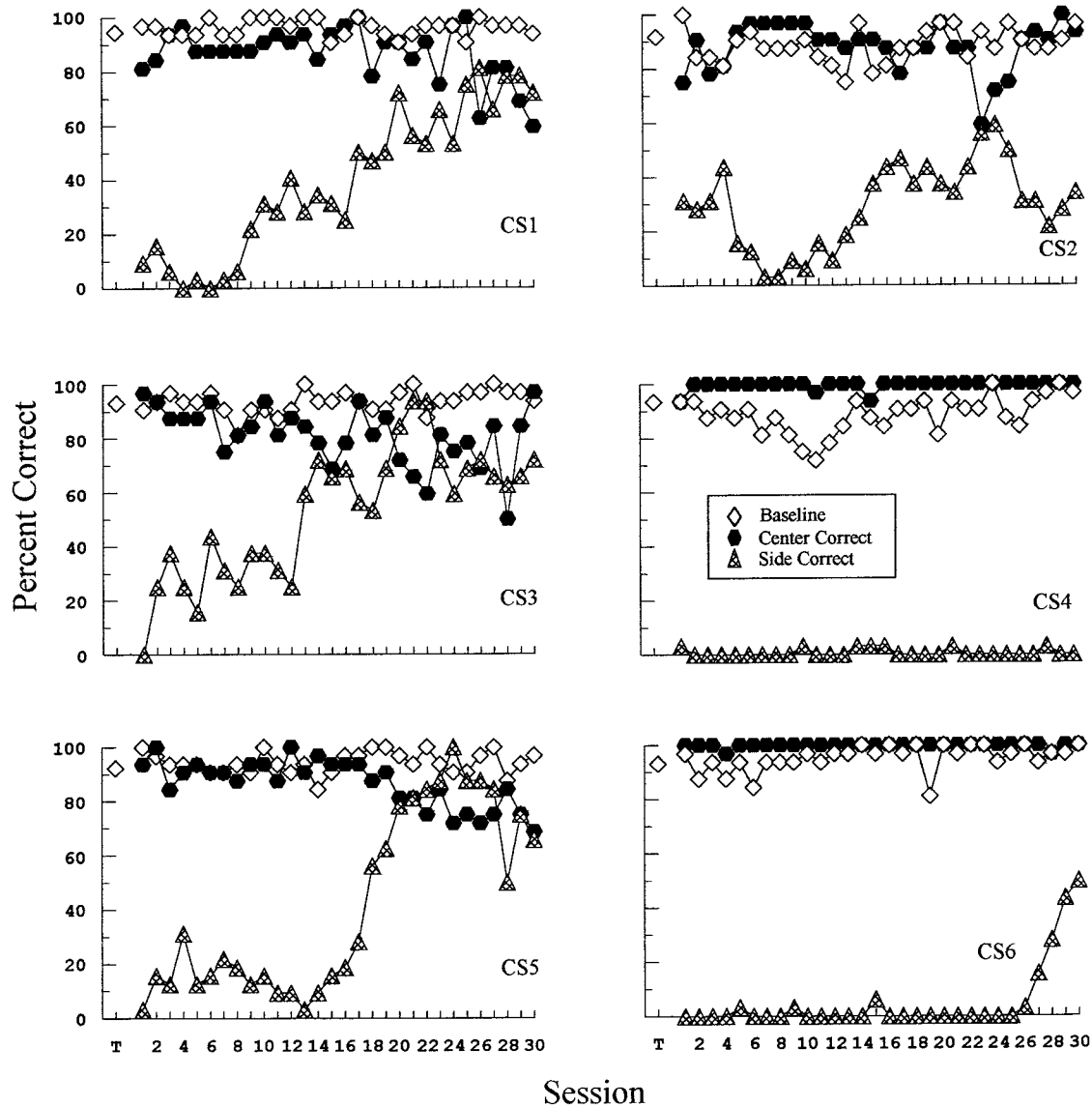
Fig. 8. Percentage correct for each subject in Group CS for 30 test sessions in Experiment 3. Average performance over the last five training sessions preceding testing is indicated by T.

nearly all birds. By contrast, the side-correct trials consistently yielded poor performances. Although the percentages of correct choices on side-correct trials improved noticeably over sessions for 4 of the 6 CS birds and 3 of the 6 MS birds, only 3 subjects (Birds CS5, MS2, and MS5) achieved accuracy levels comparable to those of baseline trials.

The question motivating this experiment was: Would birds accurately match a sample regardless of where it appeared if they had

prior experience doing so with other samples? The answer appears to be "no." Even with prior moving-sample training, Group MS birds showed marked disruption in their performances on moving-sample trials with other stimuli. In addition, the disruptive effect in this group was just as great as in the group without prior experience with moving samples (Group CS). In short, sample location was a salient stimulus feature for both groups.

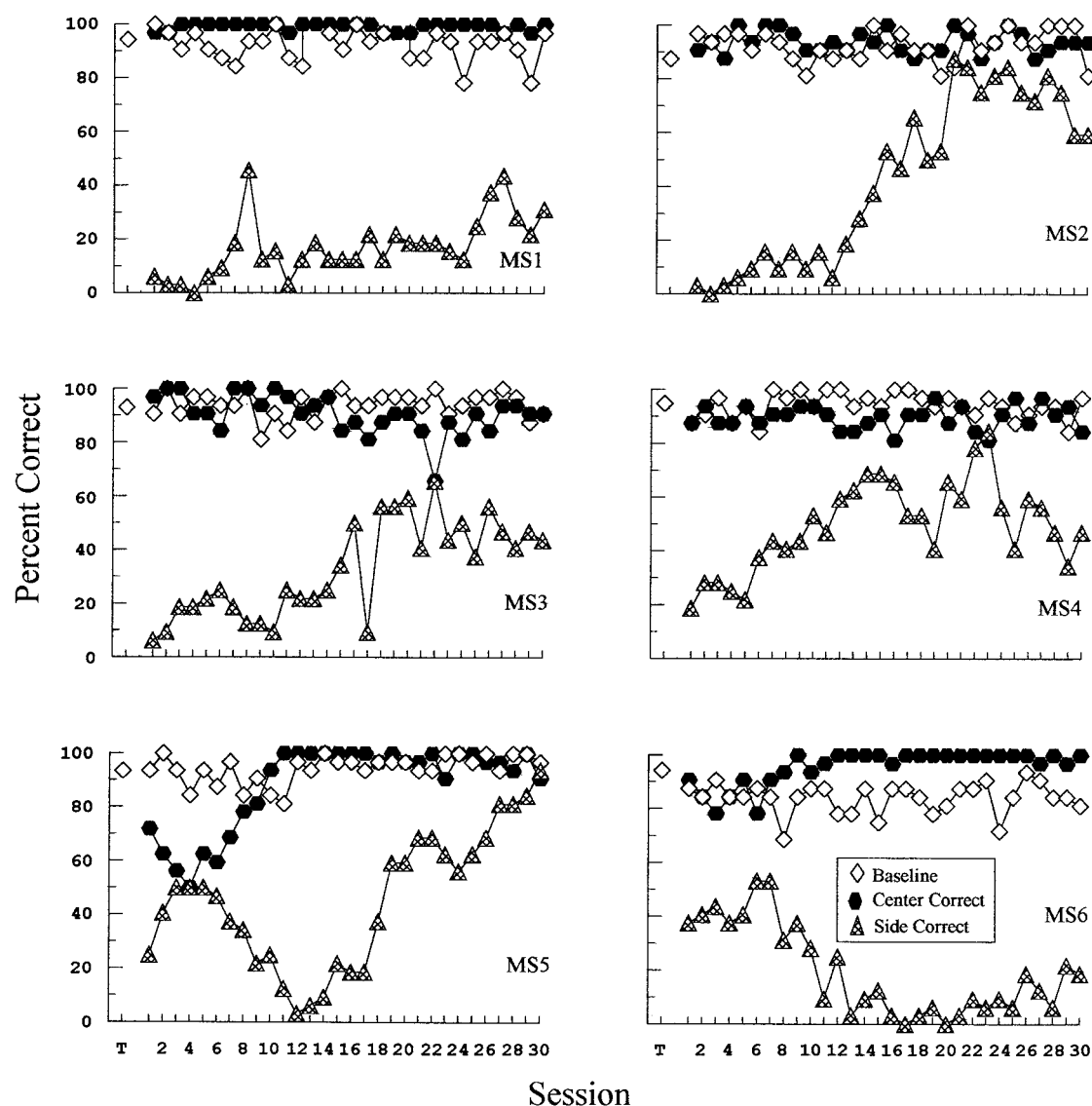Once again, the disruptive effect of moving

Fig. 9.   Percentage correct for each subject in Group MS for 30 test sessions in Experiment 3. Average performance over the last five training sessions preceding testing is indicated by T.

the line samples from the center to one of the side keys depended upon where the correct comparison appeared. In both groups, birds frequently chose the correct comparison when it appeared on the center key (center-correct trials), but they very infrequently chose the correct comparison when it appeared on the side key (side-correct trials). As before, this pattern of results apparently arose because on trials on which the sample appeared on a side key, birds simply pecked the closer of the two comparison keys (i.e.,

the center key). Thus, although the center-correct trial data might otherwise suggest that there was transfer of matching to novel sample locations, the side-correct data indicate quite clearly that the originally learned sample-comparison relations did not, in fact, transfer to novel locations.

GENERAL DISCUSSION

When the sample stimulus in pigeons' identity MTS varies among all three keys after

training only with the center key, choice accuracy drops substantially. This drop primarily occurs because birds do not consistently choose the correct comparison when the sample appears on a side key. Baseline accuracy (i.e., accuracy of comparison choice following a center-key sample) is largely unaffected. Moreover, we observed a moving-sample decrement in performance with line-orientation stimuli (Experiment 1) and hue stimuli (Experiment 2) and following training on either simultaneous or zero-delay matching (Experiments 1 and 2). The latter finding indicates that turning off the sample as the comparison stimuli appear does not reduce control by sample location relative to that observed in simultaneous MTS (see also Iversen et al., 1986). Moreover, our results show that the contribution of sample location to matching performances observed in monkeys (Iversen et al.) and in rats (Iversen, 1997) is not unique to those species. Pigeons, too, are sensitive to where the matching stimuli appear.

Experiment 3 was perhaps the most impressive in this regard. The results from that experiment indicate that sample location is such a powerful cue that even *training* pigeons to match one set of samples no matter where they appear does not eliminate, or even diminish, control by location when matching involves a completely different set of stimuli. In Experiment 3, test-trial performances of pigeons that received prior moving-sample training with a set of matching stimuli different from those on which they were tested were indistinguishable from the performances of pigeons that had received traditional (fixed-location) training. Not only did birds with prior moving-sample experience (Group MS) fail to choose more accurately than the inexperienced birds (Group CS) on the first line-matching test session, but they also showed no evidence of more rapid recovery of line matching with repeated testing. In short, no matter what their prior history in regards to where matching stimuli could appear, pigeons did not correctly match a formerly center-only sample when it later appeared on a side key.

One explanation for this finding is that the experienced birds (Group MS) had learned that only certain samples (i.e., hues) could appear anywhere (and, thus, to ignore sam-

ple location for these stimuli), whereas other samples (i.e., lines) appeared only on the center key. Alternatively, these birds may have learned during initial training to match six compound samples (as opposed to two element samples): center-red, center-green, left-red, left-green, right-red, and right-green. In other words, perhaps location was a controlling characteristic of matching performance even with the hues.

In any event, the failure of moving-sample training to generalize to new stimuli in Experiment 3 is noteworthy. After all, although some initial disruption of performance was to be expected by changing from constant-location line samples in training to varied locations in testing (Thomas, 1985), the effect should have dissipated more quickly in Group MS if prior moving-sample training with hue stimuli was at all effective in reducing control by location. But this was clearly not the case: Acquisition of accurate line matching with varied sample locations was no more rapid for these birds than for birds whose prior matching experience involved hue samples appearing only in a center-key location. In short, there appeared to be a complete lack of generalization of "location irrelevance" from the hues to the lines in Group MS. Although the reasons for this are not immediately clear, the results nonetheless underscore how difficult it may be to overcome control by location in the typical MTS paradigm.

Another noteworthy outcome of the present study was the tendency of many birds to peck the comparison on the center key when the sample appeared on a side key. Across birds and experiments, the percentage of center-key choices on side-key sample trials during the first five test sessions ranged from 39.69% to 99.69%, with a mean of 73.33%. As mentioned earlier, this might reflect a bias to peck the closest comparison on these trials. If so, one possible strategy for overcoming the bias, and thus permitting a more sensitive test of "location-independent" matching, would be to provide matching training in which the samples appear *only* on a side key. Afterwards, birds would be tested with the samples appearing on the center key. In this test, both the left and right comparisons are equidistant from the sample, so any "closest key" bias could not differentially affect com-

parison choice. Perhaps under these conditions, birds would show some evidence of transfer of matching to a new (center-key) location. If not, then the response bias mentioned above and that we observed here would appear to be only another manifestation of a lack of transfer, not its source.

Iversen (1997) recently reported a similar response bias in rats that were initially trained to nose poke one of two side-key comparisons after viewing a center-key presentation of a steady-light versus a flashing-light sample in a simultaneous MTS procedure. Following acquisition, sample location was varied across the three keys (with the comparisons appearing on the remaining two). Iversen found that matching accuracy fell to approximately 50% correct on trials with a side-key sample and that with repeated testing, 2 of the 3 rats developed a tendency to respond to the center-key comparison on these test trials. Moreover, subsequent explicit training with only side-key samples was ineffectual in eliminating, or even reducing, the center-key bias. Our findings, then, are not unique to pigeons' MTS.

The present study adds to a body of literature demonstrating the importance of sample location in MTS with animals (Iversen, 1997; Iversen et al., 1986; Lipkens et al., 1988). Our experiments also indicate that location is so powerful a cue that training with variable locations does not weaken its control with other sample stimuli. In these types of tasks, then, the sample for the animal is not simply whatever stimulus element appears on a key (e.g., "red" or "vertical line"). Instead, the samples appear to be compound stimuli comprised of at least two elements: (a) the nominal stimulus described by its physical appearance and (b) the location at which it appears (e.g., "center-red" or "left-vertical"). Because symmetry tests are typically conducted using multikey MTS procedures, the standard training and testing procedures are highly unlikely to reveal evidence for this type of emergent relation in pigeons and other nonhuman animals. The "failure" may have little to do with the animals' inability to demonstrate symmetry (cf. Schusterman & Kastak, 1993) but, rather, may reflect the fact that the trained and tested stimulus relations are not what the experimenter thinks they are. For a proper test of symmetry, those re-

lations must be location independent. The present results, by contrast, indicate a high degree of location dependency in pigeons' MTS.

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ELECTION OF NEW EDITOR OF JEAB

At the annual meeting of the Board of Directors of the Society for the Experimental Analysis of Behavior, Kennon A. Lattal was named as editor-elect of the *Journal of the Experimental Analysis of Behavior.* His term will begin on September 1, 1999, and extend until August 31, 2003.